Some factors affecting foraging and habitat of Ring Ouzels *Turdus torquatus* wintering in the Atlas Mountains of Morocco

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Quelques facteurs affectant la recherche de nourriture et l'habitat du Merle à plastron *Turdus torquatus* hivernant dans l'Atlas marocain. L'étude présentée avait pour objet d'examiner le rôle des baies de genévrier comme source principale de nourriture des Merles à plastron *Turdus torquatus* hivernant dans l'Atlas marocain. Des deux espèces de genévrier examinées, l'Oxycèdre *Juniperus oxycedrus* est la plus répandue, mais se trouve en faible densité dans d'autres milieux boisés. Dans les 43 sites étudiés dans le Moyen et Haut-Atlas, les Merles à plastron ont été observés uniquement à l'intérieur ou près des bois de Genévrier de Phénicie *J. phoenicea*. Malgré le fait que le nombre de baies de genévrier mûres dans de tels bois varie beaucoup (de $2{,}7 \times 10^4$ à $2{,}6 \times 10^6$ par ha), il apparaît que le niveau des dégâts causés aux arbres par des coupes, et le niveau général de perturbation, sont des facteurs plus déterminants plus importants pour la présence des Merles à plastron que le nombre de baies. Les bois de genévriers rencontrés pendant cette étude sont dégradés et vieillissants, et il n'y a pas de régénération, ce qui suggère un déclin à long terme avec des implications potentielles pour la future disponibilité de genévriers et la survie des Merles à plastron.

Summary. This study aimed to shed light on the role of juniper berries as the principal food source for Ring Ouzels *Turdus torquatus* wintering in Morocco's Atlas Mountains. Of the two juniper species surveyed, Prickly Juniper *Juniperus oxycedrus* was the most widespread, but occurred at low densities in other types of woodland. Of 43 sites surveyed in the Middle and High Atlas, Ring Ouzels were only seen in or close to Phoenician Juniper *J. phoenicea* woodland. Although the number of ripe juniper berries in such woodland ranged from 2.7×10^4 to 2.6×10^6 per ha, the degree of damage to the trees from cutting, indicative of general levels of disturbance, appeared to be a stronger determinant of Ring Ouzel presence than did the number of berries. Juniper woodland encountered in this study was in a degraded and ageing state with no recruitment by younger trees, suggesting a long-term decline with potential implications for juniper availability and Ring Ouzel survival in the future.

Ring Ouzel *Turdus torquatus* breeds in upland areas of Europe and Fennoscandia, and winters around the Mediterranean, North Africa and the Middle East (Snow & Perrins 1998). Nominate *T. t. torquatus*, which breeds in Britain and Fennoscandia, winters in southern Spain and north-west Africa, predominantly in the Atlas mountains, from Morocco to Tunisia (Wernham *et al.* 2002).

Although populations in continental Europe (*T. t. alpestris*) appear largely stable, there has been a decrease in numbers and a contraction of range in Spain and Britain (Heath *et al.* 2000, Wotton *et al.* 2002) and the species is now included on the UK Red List (Gregory *et al.* 2002). The decline has been attributed to a range of factors including habitat change, disturbance, global climate change, predation, pollution, increased competition from Blackbirds *T. merula*, and problems on the migration routes or wintering grounds (Tyler & Green 1994, Murray *et al.* 1998, Stott *et al.* 2002), but the exact reason remains unclear (Burfield 2002). Burfield (2002) suggested that as UK birds appear to share wintering grounds with birds from stable continental populations, factors causing this decline are most likely to be acting in the breeding grounds or migration routes. Nevertheless, the ecology of Ring Ouzels during the 5–6 months when they are migrating and wintering outside their breeding area is poorly understood.

The species' winter food requirements are not well understood, although they have been reported mainly eating juniper berries in Morocco and Algeria (Heim de Balsac 1931, Heim de Balsac & Mayaud 1962, Arthur *et al.* 2000). In the Sierra

Nevada of Spain, Zamora (1990) found juniper berries, supplemented by arthropods, to constitute the Ring Ouzel's main diet in winter. Zamora also suggested that this restricted diet reflected the limited choice of food in this area, as Ring Ouzels wintering elsewhere in Spain ate other berry species where available.

Four species of juniper occur in Morocco: Prickly Juniper *Juniperus oxycedrus*, Phoenician Juniper *J. phoenicea*, Spanish Juniper *J. thurifera* and Common Juniper *J. communis*. The first three are common at moderate to high altitudes in Morocco, but Common Juniper is rare, growing only on high mountains (Jahandiez & Maire 1931).

In Morocco, Ring Ouzels are common to locally abundant winter visitors, especially in the Central and Eastern High Atlas (Thévenot *et al.* 2003). They are rare and irregular in the western Middle Atlas, but more regular in the eastern part. Thévenot *et al.* (2003) state that they occur in open coniferous woodland on stone slopes from 1,000 m to 2,700 m, especially among *J. phoenicea and J. thurifera* at 1,800–2,200 m or in mixed *J. oxycedrus* / *Quercus ilex* woodland, often near rivers or waterholes.

The present study of Ring Ouzels overwintering in the Atlas Mountains focused primarily on their relationship with juniper and factors which may influence the availability of juniper berries, and hence the survival of Ring Ouzels in winter.

Methods

During two visits to Morocco in the winters of 1993 and 2000, a total of 43 sites was examined along two transects through the Middle and High Atlas, respectively, plus an additional site (3.1) in the central High Atlas (Fig. 1). Sites representative of a range of habitats were assessed for the presence of Ring Ouzel, juniper and other berry-bearing species, potential food for Ring Ouzels, as they were encountered along the transects. Food availability and pressures on food sources were evaluated.

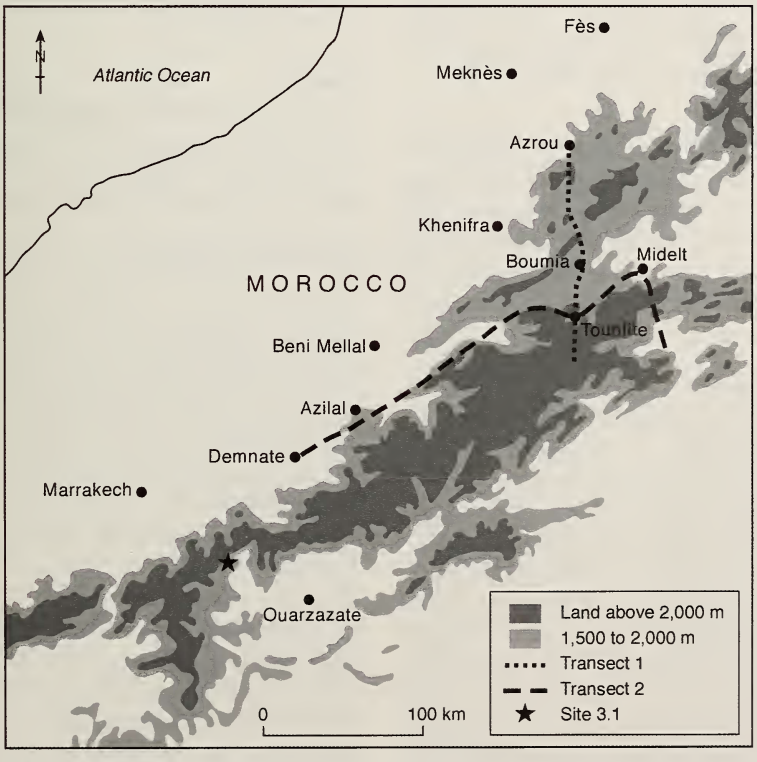


Figure 1. Map of the Middle Atlas and High Atlas Mountains of Morocco showing the positions of Transects 1 and 2 and Site 3.1.

Carte du Moyen et Haut-Atlas marocain, indicant la localisation des Transects 1 et 2 et du Site 3.1.

Transects
Transect 1 ran *c.*110 km, north to south from Azrou, across the Middle Atlas, to Tounfite and Midelt on the north-east slopes of the High Atlas (Fig. 1). The preliminary visit, in December 1993, aimed to locate Ring Ouzels and potential berry sources, focusing on juniper. Qualitative observations were made at nine sites (1.1–1.9). Juniper-rich sites were located with the aid of information from Eaux et Forêts (Moroccan Water and Forestry Department) and from Berber farmers and shepherds.

Transect 2, in January 2000, ran primarily east to northeast along the northern slopes of the High Atlas from Demnate in the west to Midelt, *c.*230 km to the east, and crossed Transect 1 at Tounfite; so sites 1.7 and 2.19 are the same. On the second transect, 33 locations (2.1–2.33) representing a series of distinct habitats, at least 1 ha in extent, ranging from ploughed arable land to forest, were assessed as they were encountered. However, greater emphasis was given to areas containing juniper and other berry-bearing species as these were likely to be more important to Ring Ouzels. An additional juniper-rich site (3.1) *c.*20 km south of Taddert was surveyed (Appendix 3).

Ring Ouzel density
At locations where Ring Ouzels were observed, on Transect 2 and site 3.1, they were counted along one 100 × 50 m transect through each site. Surveys were carried out in the morning only, between 09.00 and 12.00 hrs. Presence or absence of other *Turdus* spp. and their scats on and around juniper trees was noted.

Juniper tree parameters
Quantitative data on juniper trees were collected in Transects 2 and site 3.1, i.e. canopy diameter, tree height, number of trees per ha in 10 ˜ 10 m^2 quadrats chosen at random (see Table 2 and Appendix 3). The degree of cutting damage to trees was scored on a scale of 0–5 (0 = no visible damage; 5 = only stump remaining). Stands of juniper were classified as 'undegraded' if the mean scored was <2.5 and 'degraded' if they scored >2.6. At some sites (sites 2.1–2.19, 2.29 and 3.1) the number of juniper stumps per ha was counted and at Tounfite the diameter of juniper trunks at 0.25 m above ground was also recorded.

Juniper berry parameters
Ripe and unripe berries were counted per 0.25 m^2 of tree canopy surface on the north, south, east, west aspects and at the top of ten randomly selected Phoenician and Prickly Juniper trees at selected sites. The number of ripe and unripe juniper berries per ha was extrapolated by calculating the surface area of juniper trees. The proportion of aborted or insect-parasitised berries was calculated at several sites and the berry diameter of Phoenician Juniper and Prickly Juniper berries was measured with a micrometer.

Casual observations and coordinates
Signs of pressures on juniper tree density, survival and hence habitat quality were noted, as well as other factors that might effect survival of Ring Ouzels, e.g. habitat degradation, disturbance and proximity of sites to water. Other berry-bearing species were recorded along with topography, altitude and compass orientation of escarpments. For Transect 1 bearings or altitude were approximated using maps, but for Transects 2 and site 3.1, a Magellan GPS 2000XL global positioning system was employed.

Results
In total, 43 sites were investigated in the two phases of this study over an altitude range of 1,003–2,208 m (Appendices 1–2), and 11 distinct habitat types were discerned (Table 1).

Occurrence of juniper
Three species of juniper were encountered: Prickly, Phoenician and Spanish Juniper. Prickly Juniper formed bushes or small trees averaging 2.8 m in height and, being recorded at 21 of the 43 sites at 1,231–2,208 m, was the most widespread species. It grew mainly as a secondary species in stands of Phoenician Juniper as 5–20% (mean 9%) of the trees present or in Holm Oak *Quercus ilex* woodland as 5–50% (mean 21%). At two sites (1.9 and 2.2), Prickly Juniper was the dominant tree species.

Phoenician Juniper woodland was encountered mostly at the eastern end of the High Atlas, around Tounfite and south of Midelt, but also in the Central High Atlas, south of Marrakech at 1,918 m (3.1), at 1,003 m near Demnate (2.1) and in lower numbers in the Middle Atlas at 1,800 and 2,000 m (1.4 and 1.6). It grew as rounded

Table 1. Occurrence of Ring Ouzels *Turdus torquatus* and other thrushes *Turdus* spp. in 11 different habitats surveyed in 1993 and 2001, and the presence of berry bearing species.

Tableau 1. Présence du Merle à plastron *Turdus torquatus* et d'autres grives *Turdus* spp. dans 11 habitats différents examinés en 1993 et 2001, et la présence d'espèces produisant des baies.

Vegetation type and condition*	Berry-bearing species present**	Number of sites surveyed	Number of sites with Ring Ouzels	Other thrushes present
Holm Oak woodland	Prickly Juniper *J. oxycedrus*	7	0	Blackbird *T. merula*
Undegraded Phoenician Juniper woodland	Phoenician Juniper *J. phoenicea* Prickly Juniper *J. oxycedrus* (Spanish Juniper *J. thurifera*) (Hawthorn *Crataegus monogyna*) (Mistletoe *Viscum cruciatum*) (Dog Rose *Rosa canina*)	7	6	Blackbird *T. merula* Mistle Thrush *T. viscivorus* Song Thrush *T. philomelos* Redwing *T. iliacus*
Degraded Phoenician Juniper woodland	Phoenician Juniper *J. phoenicea* Prickly Juniper *J. oxycedrus* (Hawthorn *C. monogyna*)	5	0	Blackbird *T. merula* Mistle Thrush *T. viscivorus* Redwing *T. iliacus*
Undegraded/degraded Prickly Juniper woodland	Prickly Juniper *J. oxycedrus* (Lentisc *Pistacia lentiscus*)	2	0	Blackbird *T. merula* Mistle Thrush *T. viscivorus* Redwing *T. iliacus*
Degraded Spanish Juniper woodland	Spanish Juniper *J. thurifera* (Prickly Juniper *J. oxycedrus*)	1	0	None
Scrub woodland	Hawthorn *C. monogyna* Mistletoe *V. cruciatum* Dog Rose *Rosa canina* (Prickly Juniper *J. oxycedrus*)	6	1	Blackbird *T. merula* Mistle Thrush *T. viscivorus* Song Thrush *T. philomelos* Redwing *T. iliacus*
Cedar woodland	None	5	0	Blackbird *T. merula*
Plantation—pine or olive	None	3	0	None
Low herb and tussock grassland	None	2	0	None
Arable land	None	4	0	None
Bare stony ground	None	1	0	None

* Condition of vegetation: Undegraded = mean score for tree damage of 0–2.5; Degraded = mean score for tree damage of 2.6–5.0
**Scarce species in parentheses

conical trees on bare stony ground, averaging 3.5 m in height, at 1,780–1,928 m at 15 of the 43 sites studied, at densities of 7.6–84 trees per ha and was invariably the dominant species. At Tounfite, some individuals reached >8 m with trunk diameters up to 0.6 m (Fig. 2). Table 2 presents parameters for juniper trees at seven sites containing Phoenician Juniper, and further details are provided in Appendix 3.

Spanish Juniper, albeit severely degraded by cutting, was encountered at Inifif (1.5), near Col du Zad, in the Middle Atlas. In the High Atlas, it was found as an occasional secondary species to Phoenician Juniper at sites 2.19 and 3.1 at altitudes of *c.*1,920 m (Appendices 1–2). The trees were all *c.*3 m in height.

Condition of juniper trees

All juniper-rich sites had damaged trees, ranging in severity from removal of a few lateral branches to total destruction leaving splintered stumps (Figs. 3–4). On a scale of 0–5, all Phoenician Juniper sites contained damaged trees with nearly half rated at above 3 (moderate damage to only stump remaining) (Table 2). The situation was similar for Holm Oak and Prickly Juniper (Appendix 2). Local people with donkeys carrying bundles of juniper wood were frequently encountered. Fig. 5d shows that damage to Phoenician Juniper correlated positively with the number of juniper stumps present (r = 0.788) and negatively with presence of Ring Ouzels (Fig 5b: r = -0.733), but not with number of ripe berries (Fig 5a: r = -0.300) or altitude (Fig 5f: r = 0.047).

Figure 2. Large Phoenician Juniper *Juniperus phoenicea* tree of *c.*8 m in near-perfect condition, near Tounfite (Site 2.19) in the eastern High Atlas, Morocco. Denuded ground from overgrazing can be seen (Colin Ryall)

Grand Genévrier de Phénicie *Juniperus phoenicea* d'environ 8 m en état quasi parfait, près de Tounfite (Site 2.19) dans le Haut-Atlas marocain oriental. On peut voir le sol dénudé par le surpâturage (Colin Ryall)

Figure 3. Large juniper tree in advanced stage of progressive destruction from firewood collection near Aguelmame de Sidi Ali (Site 1.4) in the Middle Atlas, Morocco (Colin Ryall)

Grand genévrier en état avancé de destruction progressive par la coupe de bois de chauffe, près d'Aguelmame de Sidi Ali (Site 1.4) dans le Moyen Atlas marocain (Colin Ryall)

Stumps of younger trees usually showed resprouting from the base but this was absent in older stumps.

All juniper woodland was heavily grazed by sheep and browsed by goats, with the ground totally denuded of vegetation (Fig. 3) and with copious animal droppings. No juniper seedlings or young trees were found. It was common to encounter juniper woodland in the process of being cleared for agriculture, e.g. at Demnate and Tounfite, and even lone junipers in ploughed fields, e.g. west of Boumia and south of Azrou.

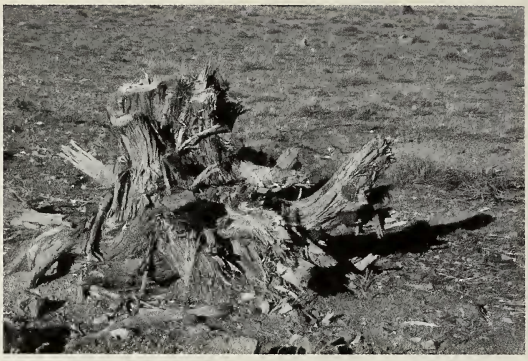


Figure 4. Stump of a large juniper destroyed from firewood collection near Tounfite (Site 2.16) in the eastern High Atlas, Morocco (Colin Ryall)

Souche d'un grand genévrier détruit par la coupe de bois de chauffe, près deTounfite (Site 2.16) dans le Haut-Atlas marocain oriental (Colin Ryall)

Juniper berries

The number of berries on juniper and the ratio of ripe to unripe were very erratic, between sites and between trees at each site (Table 2). Mean ripe berry densities for Phoenician Juniper trees ranged from 191–1,309 per m^2 of canopy and in Prickly Juniper from 0–239 per m^2, with many trees devoid of berries. Where present Phoenician Juniper always contributed the majority of berries. The number of ripe berries in stands of Phoenician Juniper ranged from 2.7×10^4–1.2×10^5 per ha (mean = 0.7×10^5) for degraded sites and 1.1×10^5–2.6×10^6 per ha (mean = 0.9×10^6) for undegraded sites (Table 2). The mean ripe berry crop for all juniper species at all sites was 6.9×10^5 per ha.

At most sites, some juniper berries were aborted (shrivelled and lacking pulp) or parasitised by insects (a small exit hole, or white scale and lacking pulp). At site 2.2, Prickly Juniper dominated, 9.3% of berries were aborted or parasitised, for Phoenician Juniper it was 18% at site 2.16, 6% at 2.17, 0.35% at 2.18 and 0.2% at 2.19 (overall mean = 6.1%). The mean berry diameters for ten trees at site 2.15 were 10.2 mm for Prickly Juniper and 10 mm for Phoenician Juniper and in both species, ripe berries were red-brown and sweet when ripe.

Table 2. Juniper tree parameters and fruit crop at seven Phoenician Juniper *Juniperus phoenicea* rich sites on Transect 2 and site 3.1, and occurrence of Ring Ouzels *Turdus torquatus*

Tableau 2. Paramètres des genévriers et production de baies dans sept localités riches en Genévrier de Phénicie *Juniperus phoenicea* le long du Transect 2 et au Site 3.1, et présence de Merles à plastron *Turdus torquatus*

Site No.	Tree spp. present*	Mean canopy diameter (m) (*SE*)	Mean number of each Juniper sp. per ha (*SE*)	Mean tree condition rating (0-5)**	Juniper stumps per ha (*SE*)	Mean berry count /m² canopy (*SE*)		Berries per ha		Ring Ouzels per 100 ˜ 50 m transect (*SE*)
						ripe	unripe	ripe	unripe	
2.15	*J p*	3.75 *(0.34)*	33.9 *(4.3)*	1.5	0	436 *(106)*	712 *(180)*	3.3×10^5	5.3×10^5	14 *(4.04)*
	J o *(0.30)*	2.17 (0.52)	1.5	2		0	0	0	0	
2.16	*J p*	3.14 *(0.22)*	7.6 *(0.76)*	3.5	9.2 *(0.55)*	1033 *(189)*	158 *(63)*	1.2×10^5	1.9×10^4	0
	J o	2.08 *(0.24)*	2.2 *(0.73)*	3.5		0	0	0	0	
2.17	*J p*	3.39 *(0.30)*	18.4 *(1.9)*	2.4	7 *(1.8)*	448 *(137)*	68 *(14)*	1.5×10^5	2.2×10^4	1 *(0.70)*
	J o	2.4 *(0.86)*	12.8 *(4.2)*	3.7		239 *(276)*	0	2.8×10^4	0	
2.18	*J p*	3.82 *(0.43)*	83.6 *(10.8)*	2.5	11.9 *(3.17)*	759 *(168)*	58 *(23)*	1.5×10^6	1.5×10^5	3.4 *(0.45)*
	J o	2.64 *(0.31)*	3.6 *(3.5)*	3		0	0	0	0	
2.19	*J p*	5.62 *(0.37)*	40 *(2.23)*	2	5.2 *(1.82)*	1309 *(224)*	92 *(80)*	2.6×10^6	1.8×10^5	7.8 *(3.45)*
	J o	2.9 *(0.78)*	16 *(4.66)*	2		0	0.8 *(0.9)*	0	0	
	J t	3.15 *(0.10)*	0.4 *(0.45)*	1		-		-	-	
2.29	*J p* *(0.55)*	2.12 *(3.16)*	20	4	30.8 *(5.13)*	191 *(191)*	157 *(157)*	2.7×10^4	2.2×10^4	0
3.1	*J p*	3.63 *(0.30)*	24.8 *(2.41)*	2.5	2 *(1.22)*	214 *(77)*	63 *(45)*	1.1×10^5	3.2×10^4	3.4 *(0.97)*
	J o	3.63 *(0.36)*	19.2 *(2.79)*	2.5		170 *(162)*	0	6.7×10^4	0	
	J t	3.1 *(0.33)*	0.8 *(0.55)*	2.5		319 *(20)*	480 *(76)*	3.9×10^3	5.8×10^3	

* *J p = J. phoenicea; J o = J. oxycedrus, J t = J. thurifera*

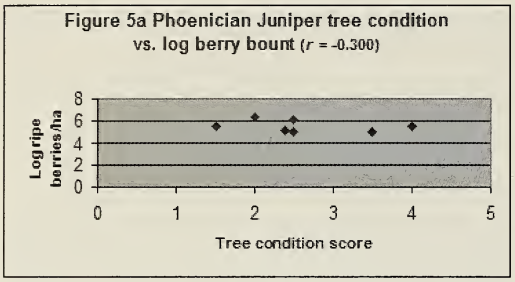
** Condition of vegetation: Undegraded = mean score for tree damage of 0–2.5; Degraded = mean score for tree damage of 2.6–5.0 (see Methods, Juniper tree parameters for further details)

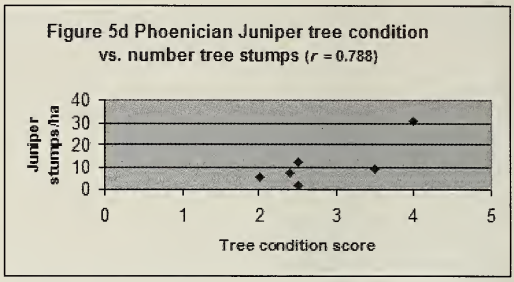
Other potential food sources

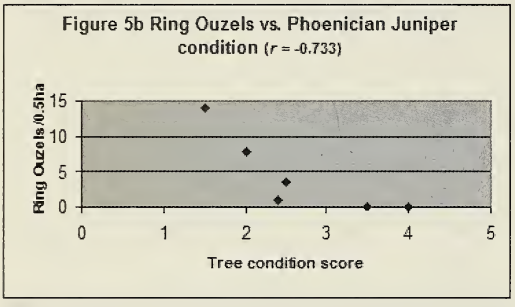
Table 1 shows that other berry species, namely Hawthorn *Crataegus* spp., Dog Rose *Rosa canina*, Red-berried Mistletoe *Viscum cruciatum* and Lentisc *Pistacia lentiscus*, were present in damper sites, such as valley bottoms, northern slopes and where overgrazing was less severe.

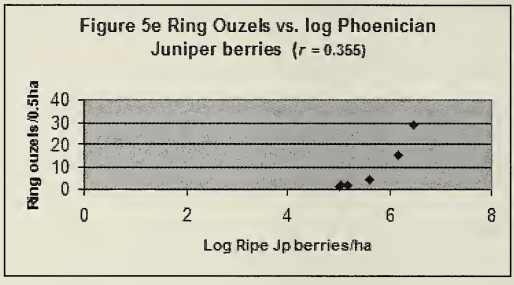
Presence of Ring Ouzels

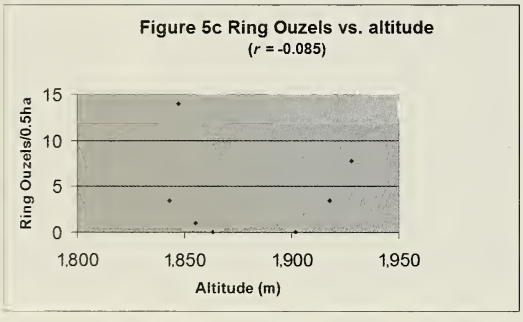
Ring Ouzels, seen at close quarters, appeared to be nominate *T. t. torquatus*. Although other species of thrush were recorded in all six types of berry rich habitat (Table 1), Ring Ouzels were only encountered in undegraded Phoenician Juniper woodland, except once where one was seen feeding on

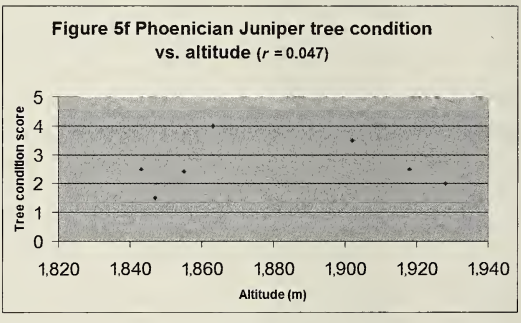












Figures 5a–f. Correlation coefficients (*r*) for a series of parameters relating to Ring Ouzels *Turdus torquatus* and juniper in the High Atlas.

Coefficients de corrélation (*r*) pour une série de paramètres concernant le Merle à plastron *Turdus torquatus* et le genévrier dans le Haut-Atlas marocain.

small rosehips in scrub close to sparse Phoenician Juniper (site 1.8). It is noteworthy that all sites where Ring Ouzels were seen or indicated by plentiful scats were less than 500 m from a source of water. Ring Ouzels were mainly in fast-moving flocks of *c.*4–30 birds accompanied by small numbers of other *Turdus* spp. (Blackbird *T. merula*, Mistle Thrush *T. viscivorus*, Song Thrush *T. philomelos* and Redwing *T. iliacus*). There was no correlation between altitude and number of Ring Ouzels seen (Fig. 5c).

Near Tounfite, Ring Ouzels' preference for Phoenician Juniper was attested by frequent sightings and copious droppings, on and around the trees. Such dense scat deposits were absent in other types of woodland. Ring Ouzels were not evident at sites containing Prickly Juniper without Phoenician Juniper, whether Prickly Juniper dominated (sites 1.9 and 2.2 only) or was secondary to Holm Oak (e.g. sites 2.3, 2.4 and 2.14). As shown in Table 2, no Ring Ouzels were recorded where Phoenician Juniper was seriously degraded (mean tree damage score >2.6), and Fig. 5b shows a strong negative correlation between condition of Phoenician Juniper trees and number of Ring Ouzels present (r = -0.733). However, the number

of ripe berries in Phoenician Juniper correlated weakly with number of Ring Ouzels seen (r = 0.355, Fig. 5e).

No Ring Ouzels were seen in the Middle Atlas during the 1993 visit (Transect 1) although at Aïn Nokra, Berber shepherds said they sometimes saw them in small groups in winter.

Discussion

This study, albeit small in scale, is a first attempt to quantify factors that may influence the survival of Ring Ouzels wintering in the Atlas Mountains and indicates areas for further elucidation.

Juniper as a food source for Ring Ouzels

All Ring Ouzels were seen in or close to Phoenician Juniper, often accompanied by smaller numbers of other *Turdus* spp., closely paralleling the observations of Snow (1952), Heim de Balsac (1931) and de Juana & Santos (1981). Heim de Balsac (1931), Blondel (1962) and Thévenot *et al.* (2003) considered both Prickly Juniper and Phoenician Juniper berries a major part of their winter diet. In the Spanish Sierra Nevada too, Ring Ouzels feed almost exclusively on juniper during the winter (Zamora 1990; pers. obs.) and their occurrence is strongly correlated with berry availability (Jordano 1993). This apparent specificity for juniper may apply only during midwinter because, as reported by other workers, Ring Ouzels occur in varied habitats during migration and then exploit other species of berry, in addition to juniper.

In this study, Ring Ouzels were only seen feeding in Prickly Juniper where it was with Phoenician Juniper, but not where it grew among Holm Oak. This may reflect overall berry availability. The berries of the two species are so similar, physical and to taste, that selection of one over the other seems unlikely. The mean ripe berry crop for all juniper sites (both juniper species) of 6.9×10^5 per ha closely matches that for Common Juniper (7×10^5 per ha) recorded in the Sierra Nevada (Garcia *et al.* 1996) but, like Jordano (1993), we found that the crop varied widely between areas. As a monoecious species (bearing male and female flowers on the same plant), all Phoenician Juniper trees can potentially bear berries, whereas in Prickly Juniper and Spanish Juniper, being dioecious (bearing male and female flowers on separate plants), only female trees (*c.*50%) can do so. The zero berry counts in Prickly Juniper at several sites may be due to a concentration of male plants or to a local berry failure in female trees. Jordano (1991) pointed out that the monoecious state in Phoenician Juniper is variable but is more than 90% in Morocco. Thus Prickly Juniper must usually contribute a small proportion of the total berry crop where both species occur.

As wide-ranging, opportunistic feeders, Ring Ouzels may be attracted primarily to extensive areas of juniper, e.g. Phoenician Juniper woodland, with high berry densities and low levels of disturbance, thus maximising foraging success, rather than to isolated patches or individual fruiting trees, e.g. Prickly Juniper, outnumbered amongst non-berry bearing species, e.g. by Holm Oak, though these may serve as stop-off points for migrants.

The condition of Phoenician Juniper trees, as well as number of berries, seems to be a key determinant of the presence of Ring Ouzel. We only found Ring Ouzel at five sites where cutting damage to Phoenician Juniper was low, but not in degraded stands, even with good berry crops. At an intermediate level of cutting, where trees still produce a good berry crop, disturbance from the frequent visits by small-scale wood collectors and livestock may keep Ring Ouzels away much of the time—a factor which also operates in parts of their breeding range (Burfield 2002).

However, not all berries on a juniper tree are edible. They take two years to ripen so, in autumn, trees contain both ripe and unripe berries, the ratio being variable (Table 2). In addition, a variable proportion of berries are either aborted or parasitised by insects, resulting in berries lacking pulp and with reduced nutritional value (Ionesco & Sauvage 1969). Garcia *et al.* (1999) found that Ring Ouzels rejected aborted and parasitised Common Juniper berries in the Sierra Nevada, thus necessitating greater foraging effort. The proportion of unpalatable berries can be substantial; we found levels of aborted or parasitised ranged from 0.2–18% (mean 6.1%), but Traveset & Sans (1994) recorded moth infestation levels to range from 3–50% of the crop in Phoenician Juniper in the Balearic Islands.

A further key factor in determining Ring Ouzels' choice of feeding site appears to be proximity to water. In this study, locations where the

birds were found were all within a few hundred metres of a water source. Ring Ouzels need to drink regularly whilst feeding on juniper berries. Heim de Balsac (1931), Arthur *et al.* (2000) and Thévenot *et al.* (2003) have commonly observed them drinking at rivers and waterholes in Morocco, as they do also in the Sierra Nevada when feeding on juniper berries (pers. obs.). This issue clearly needs further investigation.

Occurrence of juniper

Prickly Juniper was widespread, and like Quézel (1980), we found it associated with either Holm Oak or Phoenician Juniper woodland as a secondary or subdominant species. Phoenician Juniper was less widespread but where present was the dominant tree, forming open woodland interspersed with smaller numbers of Prickly Juniper and Holm Oak. Trees averaged 3.5 m in height, although near Tounfite some reached 8 m, the maximum for this species (Maire *et al.* 1952), with some trunk diameters of 0.6 m, indicating trees more than 500 years old, based on annular rings of stumps. In Emberger's (1938) day, Phoenician Juniper was very widespread in both the Middle and High Atlas up to 2,200 m, but we found it to be frequent if patchily distributed at 1,780–2,208 m in the High Atlas, and scarce in the Middle Atlas. Spanish Juniper has an altitudinal range of 1,800–3,150 m (Emberger 1938). Its apparent rarity in our study reflects the limits of altitudes visited. Its presence at 2,000 m near Inifif in the Middle Atlas (1.5) was also noted by Sauvage (1956).

Juniper damage and decline

Most of our sites had trees showing moderate to severe damage, which concurs with Quézel & Barbero (1981), who described stands of Phoenician Juniper as very degraded by human influence and livestock. We commonly saw local Berbers with donkeys, and even trucks, laden with juniper and Holm Oak wood. Of course, damage may be less severe at sites more remote than those in our study. All three juniper species are used for burning for cooking, heating and construction by the Berbers (Auclair 1996), and Phoenician and Spanish Junipers are used for livestock feed in droughts (Ionesco & Sauvage 1969).

We noted that stumps of smaller junipers often re-sprouted but, in older trees, some more than 500 years old, this was absent. This loss of regenerative ability with age was recognised by Emberger (1938) and Métro & Sauvage (1955). This habitat degradation is further exacerbated by the lack of recruitment of young trees due probably to a combination of overgrazing and drought, seen also in the Sierra Nevada (R. Zamora pers. comm.), and Quézel & Barbero (1981) noted a complete lack of juniper regeneration in the region of the Atlas Mountains.

Despite a statement to the contrary by Arthur *et al.* (2000), juniper is no longer being used sustainably in the Atlas. Auclair (1996) pointed out that traditional controls used to work well to preserve mountain forest but population increase in parts of the High Atlas is resulting in permanent forest loss; indeed, wood removal is twice the rate of production and stocking levels twice the sustainable level.

Lone junipers in vast areas of ploughed arable land on the lower mountain slopes and plains testify to large-scale clearance of juniper woodland. We are late in a long-term process of deforestation. In Roman times more than half of North Africa was densely forested (Blondel & Aronson 1999), whereas 17% remains in Morocco, including oak, cedar and juniper forest. Conacher & Sala (1998) observed that agricultural clearance and deforestation in the mountains of North Africa intensified from the late-18th century due to excessive woodcutting and overgrazing by sheep and goats. This scenario involves the long-term fragmentation and destruction of a key resource for Ring Ouzels. As Zamora (1990) and Jordano (1993) found in Spain, the Ring Ouzel is most probably the main dispersion vector for *Juniper* species in North Africa.

Conclusions

We focused on the occurrence of Ring Ouzels in relation to species of juniper, berry crop and degree of damage to trees. It must be recognised that this was a small-scale study, with Ring Ouzels only being detected at seven sites, and so the following conclusions must therefore be considered provisional.

The well-established link between wintering Ring Ouzels and juniper is confirmed, but this link is primarily with Phoenician Juniper, which contributes far more berries than Prickly Juniper, and therefore offers the most productive foraging option.

The presence of Ring Ouzels correlated with the condition of Phoenician Juniper. Where trees were severely damaged, indicative of a high level of human disturbance, there was no evidence of Ring Ouzel visits, even where ripe berries were plentiful.

Several factors are resulting in a long-term process of juniper woodland decline:

- unsustainable harvesting for firewood and forage
- loss of regenerative ability in the ageing stock of juniper trees
- an ageing population of juniper due to lack of recruitment of young trees from overgrazing, agricultural clearance and drought.

Burfield (2002) points out that, if UK birds share their wintering grounds with those from stable continental populations, the factors causing their decline are most likely to be acting in the breeding grounds or migration routes. However, at present, little is known of the ecology or movements of the two races, *T. t. torquatus* and *T. t. alpestris*, during the 5–6 months they are migrating and wintering in the mountains of North Africa. Neither is it known how much juniper is needed to support this Ring Ouzel population, particularly in a year with a poor berry crop and/or water is scarce near berry sources.

The total acreage of juniper woodland is unknown, as is its condition and the rates of fragmentation and loss. Juniper berry availability may not yet be a limiting factor for the species but as destruction continues this point must eventually come. Poor foraging in winter, for whatever reason, means poorer condition for migration and breeding.

Our study covered a small number of more accessible sites, during a short part of the winter period and did not include Spanish Juniper sites, which occur at higher altitudes. Nevertheless, our findings indicate aspects that future, more extensive studies could focus on:

- how much juniper is required to support the current Ring Ouzel population, in view of the variability of berry production
- the extent and status of juniper-rich habitat in Algeria and less accessible parts of the Moroccan Atlas
- the condition and rate of loss of the juniper woodland that remains
- the status of other berry species and their importance for migrating and wintering Ring Ouzels
- the importance and availability of water as a factor limiting the Ring Ouzel's ability to exploit available berry supplies.

Acknowledgements

We thank Farnborough College for financial support for this work throughout, along with the British Trust for Ornithology and Bird Exploration Fund for their assistance with the 1993 phase of the study. Thanks also to Prof. Jacques Franchimont, Zin Labaadin Afhaz and Mick Green for their assistance on the 1993 research trip, to Jeanne Capey for help with translation and to the late Rae Vernon for his helpful information. Patrick Bergier commented on a draft of this paper.

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Received 24 December 2004; revision accepted 5 July 2005

Appendix 1. Summary of the sites in Transect 1.

Annexe 1. Aperçu des sites le long du Transect 1.

Site no.	Site name	Location	Approx. altitude (m)	Site description	Juniper		Other berry species	Ring Ouzels
					spp. frequency	condition (score)		
1.1	Aguelmame Affenourir (MA)	SW of Azrou	1,800	Scrub lake, grazed grassland	None	N/A	Hawthorn Mistletoe, Rose	-
1.2	Aguelmame Affenourir (MA)	SW of Azrou	1,800	Cedar forest little ground cover	None	N/A	None	-
1.3	Aguelmame de Sidi Ali (MA)	S of Azrou	1,800	Scrub adjacent arable land, lake, river	None	N/A	Hawthorn Mistletoe, Rose	-
1.4	Aguelmame de Sidi Ali (MA)	S of Azrou	1,800	Cedar forest (moribund)	*J p* scarce *J o* scarce	4 /	None	-
1.5	Inifif (MA)	S of Azrou	2,000	*J t* woodland forestry exclosure	*J r* moderate	3	None	-
1.6	Aïn Nokra (MA)	S of Azrou	2,000	*Q ilex* woodland river valley	*J o* common *J p* scarce	3 /	Hawthorn Mistletoe, Rose	-
1.7 (2.19)	Tounfite (HA)	WSW of Midelt	1,928	*J p* woodland adjacent arable	*J p* common *J o* moderate *J t* rare	2 2 /	Hawthorn Mistletoe, Rose	+
1.8	Asselim (HA)	S of Midelt	1,600	Scrub adjacent juniper arable	*J p* moderate *J o* rare	3	Rose	+
1.9	S of Khénifra	S of Khénifra	/	*J o* scrub	*J o* dominant	1	Rose	-

Key:

MA = Middle Atlas; HA = High Atlas

J p = Juniperus phoenicea; J o = J. oxycedrus; J t = J. thurifera

/ = Data not collected

Condition of vegetation: Undegraded = mean score for tree damage of 0–2.5; Degraded = mean score for tree damage of 2.6–5.0 (see Methods, Juniper tree parameters for further details)

+ = Ring Ouzels present; - = Ring Ouzels absent

Appendix 2. Summary of the sites in Transect 2 and of Site 3.1.

Annexe 2. Aperçu des sites le long du Transect 2 et du Site 3.1.

Site no.	Location	Coordinates	Alt itude (m)	Site description	Juniper		Other berry species	Ring Ouzels
					spp. frequency	condition (score)		
2.1	SW of Demnate	31°38'N 07°14'W	1,003	*J p* woodland clearance for arable	*J p* dominant	3.5	*Pistacia* sp.	-
2.2	W of Azilal	31°54'N 06°42'W	1,247	*J o* woodland dense ground cover	*J o* dominant	1.5	*Pistacia* sp.	-
2.3	SE of Azilal	31°51'N 06°25'W	1,865	*Q ilex* woodland adjacent arable	*J o* moderate	4	None	-
2.4	W of El Kebab	32°43'N 05°34'W	1,231	*Q ilex* woodland adjacent arable	*J o* scarce	4	None	-
2.5	S of El Kebab	32°41'N 05°34'W	1,295	*Q ilex* woodland adjacent arable	*J o* moderate	3	None	-

2.6	SE of El Kebab	32°41'N 05°30'W	1,665	Bare ground near valley	None	N/A	None	-
2.7	Tanout-Ou-Filali	32°40'N 05°29'W	1,859	*Q ilex* woodland bare ground	*J o* scarce	3	None	-
2.8	Sidi Tiar	32°40'N 05°27'W	2,070	Plantation (pine) adjacent arable	*J o* scarce	4	Hawthorn Mistletoe, Rose	-
2.9	W of Boumia	32°39'N 05°24'W	1,842	Arable land adjacent tussock herbage	None	N/A	None	-
2.10	N of Tounfite	32°40'N 05°17'W	1,637	Arable land Totally denuded	None	N/A	None	-
2.11	N of Tounfite	32°34'N 05°16'W	1,813	Arable land adjacent tussock herbage	None	N/A	None	-
2.12	N of Tounfite	32°32'N 05°16'W	1,870	Scrub adjacent tussock herbage	None	N/A	None	-
2.13	N of Tounfite	32°31'N 05°16'W	1,895	*Q ilex* woodland adjacent arable	*J o* scarce	3	None	-
2.14	N of Tounfite	32°30'N 05°15'W	1,874	*Q ilex* woodland bare stony ground	*J o* common	3	Hawthorn, Mistletoe	-
2.15	N of Tounfite	32°29'N 05°14'W	1,847	*J p* woodland near river, near farm	*J p* dominant *J o* moderate	1.5 2	Hawthorn, Mistletoe, Rose	+
2.16	N of Tounfite	32°31'N 05°12'W	1,902	*J p* woodland ploughed below	*J p* dominant *J o* moderate	3.5 3.5	None	-
2.17	N of Tounfite	32°31'N 05°12'W	1,855	*J p* woodland mixed vegetation	*J p* dominant *J o* moderate	2.4 3.7	Rose	+
2.18	N of Tounfite	32°30'N 05°13'W	1,843	*J p* woodland near river	*J p* dominant *J o* scarce	2.5 3	None	+
2.19 (1.7)	E of Tounfite	32°29'N 05°10'W	1,928	*J p* woodland bare stony ground, adjacent arable	*J p* dominant *J o* scrace *J t* rare	2 2 /	None	+
2.20	SE of Tounfite	32°27'N 05°09'W	1,850	*J p* woodland near river	*J p* dominant *J o* scarce	3.5 4	Hawthorn Mistletoe	-
2.21	S of Tounfite	32°26'N 05°09'W	1,896	Scrub river gorge	None	N/A	Rose	-
2.22	S of Tounfite	32°25'N 05°09'W	1,866	Scrub river gorge	None	N/A	Rose	-
2.23	W of Tounfite	32°38'N 05°17'W	2,030	Cedar forest adjacent arable	*J p* scarce	/	Hawthorn Mistletoe	-
2.24	W of Tounfite	32°28'N 05°18'W	2,208	Cedar forest adjacent arable	*J p* scarce	/	Hawthorn Mistletoe	-
2.25	W of Tounfite	32°27'N 05°20'W	2,126	Cedar forest adjacent arable	*J p* scarce *J o* rare	/	Hawthorn Mistletoe	-
2.26	N of Boumia	32°34'N 05°11'W	1,810	Arable land adjacent tussock	None	N/A	None	-
2.27	S of Midelt	32°37'N 04°32'W	1,780	*J p* woodland boulders, tussock	*J p* dominant	4	None	-
2.28	S of Midelt	32°36'N 04°31'W	1,840	*J p* woodland boulders, tussock	*J p* dominant	2	None	-
2.29	S of Midelt	32°36'N 04°31'W	1,863	*J p* woodland boulders, tussock	*J p* dominant	3	None	-
2.30	S of Midelt	32°35'N 04°32'W	1,990	Plantation (pine) bare stony ground	None	N/A	None	-

2.31	S of Midelt	32°34'N 04°29'W	1,722	Tussock grassland low herbage	None	N/A	None	-
2.32	S of Midelt	32°34'N 04°29'W	1,466	Tussock grassland low herbage	None	N/A	None	-
2.33	Er Rich	32°34'N 04°29'W	1,308	Plantation (olive) adjacent arable	None	N/A	Rose	-
3.1	Road to Telouet	31°15'N 07°21'W	1,918	*J p* woodland Wooded valley some *Q ilex*	*J p* dominant *J o* common *J t* rare	2.5 2.5 0.25	Rose	+

Key:
J p = Juniperus phoenicea; J o = J. oxycedrus; J t = J. thurifera

/ = Data not collected

Condition of vegetation: Undegraded = mean score for tree damage of 0–2.5; Degraded = mean score for tree damage of 2.6–5.0 (see Methods, Juniper tree parameters for further details)

+ = Ring Ouzels present; - = Ring Ouzels absent

Appendix 3. Juniper density, condition and fruit crop at juniper-rich sites on Transect 2 and Site 3.1, and occurrence of Ring Ouzels *Turdus torquatus*.

Annexe 3. Densité et condition des genévriers et production de baies aux sites riches en genévriers le long du Transect 2 et au Site 3.1, et présence de Merles à plastron *Turdus torquatus*.

Site no.	Altitude (m)	Tree spp. present	Mean height (m) *(SE)*	Mean canopy diameter (m) *(SE)*	% of total trees present	Mean condition rating (0–5)	Mean berry count /m² *(SE)* ripe	unripe	Mean ROs / 100 ˘ 50 m transect
2.2	1,247	*J o*	3.1 *(0.40)*	2.25 *(0.47)*	95	1.5	298 *(64)*	0	0
		Non J			5				
2.3	1,865	*J o*	2.0 *(0.20)*	2.2 *(0.27)*	20	4	0	0	0
		Q i			80				
2.5	1,295	*J o*	1.8 *(0.16)*	2.1 *(1.5)*	30	3	4.5 *(4.8)*	*(0.5)* 0.5	0
		Q i	3.6 *(0.45)*	4.0 *(0.24)*	70				
2.7	1,859	*J o*			5	3	4.5 (4.7)	0	0
		Q i	6.2 *(0.54)*	4.6 *(0.26)*	95				
2.8	1,945	*J o*			10	4	0	0	0
		Q i	4.9 *(0.37)*	5.5 *(0.35)*	90				
2.13	1,895	*J o*			15	3	2.8	0	0
		Q i	2.4 *(0.21)*	2.15 *(0.31)*	85		*(3.6)*		
2.14	1,874	*J o*	2.0 *(0.25)*	1.9 *(0.42)*	32	3	9.6 *(10.7)*	0	0
		Q i	2.5 *(0.25)*	3.25 *(0.8)*	68				

2.15	1,847	*J p*	2.7	3.75	95	1.5	436	712	14
			(0.14)	(0.34)			*(106)*	*(180)*	*(4.04)*
		J o	2.9	2.17	5	2	0	0	
			(0.17)	*(0.30)*					
2.16	1,902	*J p*	3.5	3.14	82	3.5	1033	158	0
			(0.23)	*(0.22)*			*(189)*	*(63)*	
		J o	2.78	2.08	24	3.5	0	0	
			(0.22)	*(0.24)*					
		Cyp			9				
2.17	1,855	*J p*	3.8	3.39	12	2.4	448	68	1
			(0.40)	*(0.30)*			*(137)*	*(14)*	*(0.70)*
		J o	3.4	2.4	9	3.7	239	0	
			(0.91)	*(0.86)*			*(276)*		
2.18	1,843	*J p*	2.9	3.82	90	2.5	759	58	3.4
			(0.35)	*(0.43)*			*(168)*	*(23)*	*(0.45)*
		J o	2.5	2.64	4	3	0	0	
			(0.21)	*(0.31)*					
2.19	1,928	*J p*	5.6	5.6	40	2	1309	92	7.8
			(0.49)	*(0.37)*			*(224)*	*(80)*	*(3.45)*
		J o	2.9	2.9	15	2	0	0.8	
			(0.40)	*(0.78)*				*(0.9)*	
		J t	3.35	3.15	0.4	1	-	-	
			(0.10)	*(0.10)*					
2.29	1,863	*J p*	2.1	2.12	60	4	191	157	0
			(2.1)	*(0.55)*			*(191)*	*(157)*	
3.1	1,918	*J p*	3.8	3.63	28	2.5	214	63	3.4
			(0.53)	*(0.30)*			*(77)*	*(45)*	*(0.97)*
		J o	4.4	3.63	13	2.5	170	0	
			(0.37)	*(0.36)*			*(162)*		
		J t	3.1	3.1	0.8	0.25	319	480	
			(0.24)	*(0.33)*			*(20)*	*(76)*	

Key: *J p* = *Juniperus phoenicea*; *J o* = *J. oxycedrus*; *J t* = *J. thurifera*; *Qi* = *Quercus ilex*;; *Cyp* = *Cyperus* sp.; ROs = Ring Ouzels